Data provision and projected impact of climate change on fish biodiversity within the Desert LCC

NAMES and CONTACT INFORMATION of APPLICANTS:

P.I. / **Project Manager** – Dr. Dean A. Hendrickson, Curator of Ichthyology, University of Texas Austin, Texas Natural History Collections (TNHC), 10100 Burnet Rd., PRC176 EAST/R4000, Austin, Texas 78758-4445; tel: 512-471-9774; FAX 512-471-9775; deanhend@mail.utexas.edu

Co-P.I. – Dr. Sahotra Sarkar, Professor, Section of Integrative Biology, Division of Statistics and Scientific Computation, Department of Philosophy, University of Texas at Austin, 1 University Station, #C0293, Austin, TX 78712-1180; Phone: 512-232-7122; FAX: 512-471-7068; sarkar@mail.utexas.edu

Table of Contents

(1) Technical Proposal: Executive Summary

Freshwater fishes are globally among the most imperiled major biodiversity groups and they are especially endangered in the North American deserts of the vast binational Desert Landscape Conservation Cooperative (DLCC). The six internationally shared river basins (Gila, Sonoyta, Concepción, Yaqui, Casas Grandes, Río Grande) of the DLCC east of the Colorado harbor 72 native fish species of conservation concern. Sixty seven of those are in our study area, which includes all of the DLCC in both the US and Mexico exclusive of the already very well studied US portion of the Colorado/Gila basin. Of those, 53 are native species ranked by Nature Serve (8 G1, 5 G2, 17 G3, 8 G4, 13 G5 and 1 each GN & GX) and known from both countries, so that holistic, landscape-scale management of them will surely require binational collaboration. Excluding perhaps the Río Grande Silvery Minnow, and certainly compared to fishes of the Colorado/Gila basins, essentially all species in our study area are understudied and management of them will be, and long has been, greatly impeded not only by the intrinsic difficulties of working internationally, but by relative lack of, or inaccessibility to, basic knowledge about their distributions and conservation status. Here we propose to address that issue and directly address the DLCC's Project Task Areas A, B and C by mining data from all online and known US-based institutions holding specimen-based occurrence records from our study area. We will normalize and generally improve data quality to provide a comprehensive, high quality resource that brings together in one GIS-accessible database all of the currently very scattered and relatively un-normalized museum-based records. Because hydrographic boundaries are more relevant to fishes than are sociopolitical ones, our landscape-scale project scope is driven primarily by drainage divides and we therefore include the entire Río Grande drainage. Our total study area thus includes 75% of the DLCC as well as 21% of the total area of the Southern Rockies LCC, 25% of the Gulf Coast Prairie LCC, and 3% of the Great Plains LCC. A preliminary compilation of data indicates that this project will likely provide >40,000 species occurrence records for the study area. However, funding and time constraints will force us to focus our efforts on data for the Río Grande basin, which will receive more rigorous and thorough normalization, and manual georeferencing with precision estimates, than will data for the remainder of the study area. In the Río Grande, we will also do basic quality control on taxonomy and georeferencing following published protocols [1] and use the data to produce Species Distribution Models (SDMs) for selected priority, special interest native and invasive fishes. SDMs will be constructed for present conditions and three projected climate change scenarios to allow us to assess current and projected future status throughout each species' range, thus filling vast information gaps throughout data-poor areas in Mexico that might prove vital as source or sink habitats. On-the-ground resource management and biodiversity sustainability planning will benefit since projected future distributions will identify landscape-level areas of conservation and restoration priority that may not presently be of high priority, but that may become so in the future. The varying projections under varied climate change scenarios will allow for quantitative assessment of uncertainties. Both the raw occurrence data and current and future SDMs will be valuable tools for diverse future work on regional aquatic biodiversity sustainability in the face of climate change. (Project duration: 2 years - 1 Sept., 2011 to 31 Aug., 2013)

(2) Technical Proposal: Technical Project Description

(a) Describe the goals of the work in very specific terms:
The goal of our proposed work is to produce data and decision support tools for the conservation, restoration, and management of U.S. priority freshwater fishes in drainages shared by the U.S. and Mexico throughout the DLCC (see Figure 1). The project will begin by compiling and normalizing biodiversity data for all fishes occurring in internationally shared drainages of the DLCC, exclusive of the Colorado and Gila drainages. We will then focus on the Río Grande drainage where we will model current distributions of selected special interest fishes (see Table 1) based on environmental (climatic and topographic) variables known to be of ecological relevance. We will then project the models into the future under each of three different climate change scenarios from the most recent Intergovernmental Panel on Climate Change (IPCC, http://www.ipcc.ch/) report [2]. The climate prediction scenarios used will be the most conservative (B1), an intermediate (A1B), and the most extreme (A2), on the assumption that these will quantify the range of uncertainty regarding results and increase robustness of inferences common to all three scenarios. The results will demonstrate how changing climates will impose directional pressures on the species studied that will likely tend to shift their distributions. Given the results of similar projections we have done for Texas freshwater fishes (see Figures 5 & 6), we expect that the suitable climatic habitats of at least some species of interest will tend to be pushed across the international border, demonstrating and quantifying the importance of managing sooner, rather than later, to protect habitats on both sides of the border and maintain connectivity among them. Even if our hypothesis is found false and preferred habitats do not appear to shift, the DLCC and on-the-ground resource management will benefit by being so informed and having comprehensive, high quality data on all fishes in their broad geographic scope for future analyses.

(b) Explain how the project will enhance the management of natural and cultural resources that affect or are affected by water resources management in a changing climate within the Desert LCC.
This project will benefit and enhance management of DLCC aquatic resources within the U.S. by addressing information gaps in biodiversity data for portions of the ranges of U.S. imperiled and invasive fish species within Mexico, as well as improving forecasting of species' responses to future climate change. The results of this project will provide an accurate and tractable perspective of fish species' current populations and distributions and their future status, incorporating habitat associations throughout their full distribution.

Fully aware of restrictions imposed by the program to which this proposal is being directed that do not allow work outside of the U.S., we propose to do all work in our laboratories in Austin, TX, employing only U.S. citizens and using only data from U.S. institutions and other data freely available through international biodiversity data portals. While the resultant lack of, or partial inclusion of data from Mexican institutions may at first glance seem to be a major limitation, that is not the case. Paradoxically, the very long history of extensive collection of Mexican fishes by U.S.-based researchers has resulted in most of the data on Mexican fishes being held by U.S. institutions. The

amount of additional data available from Mexican institutions, but that will not be used in this project, is relatively small compared to what we will compile. However, the Mexican data are important, especially for their inclusion of more recent collections than are typically found in U.S. collections, and the DLCC is advised to plan to eventually incorporate it in the database this project will initiate once funding becomes available to support collaborations with Mexican institutions.

Figure 1. Study area and LCCs. We will compile and normalize freshwater fish occurrence data for the entire DLCC exclusive of the Colorado/Gila basin. All data for the Río Grande drainage will be manually georeferenced with precision estimates and, for priority species in this basin, Species Distribution Models will be produced and projected onto future climates.

The raw occurrence data produced and made digitally available by this project will certainly be a strong and indispensable foundational resource for diverse on-the-ground work on landscape-level aquatic biodiversity sustainability and particularly for the important historic perspective of the fauna that it will provide. The products of this project will be applied by the DLCC and partners for more effective resource management, taxonomic studies, environmental modeling, predictive distributional studies (as proposed here), species association ecology, and evolutionary and ecological history, and find application in conservation network planning. Additionally, if on-the-ground management in the U.S. portion of the DLCC is to be effective, system response to climate change needs to incorporate and prepare for all species' contingencies, without geographic restrictions typically imposed by the international border. It is thus critical that biodiversity data used as a foundation for species assessments and resource planning

3

decisions be as robust, accurate and comprehensive as possible. Many U.S. threatened and endangered species traverse the U.S.-Mexican border, however the occurrence data quantity or quality associated with these imperiled taxa differs immensely between U.S. and Mexican portions of the shared drainages. This project will largely rectify that geographic imbalance in data quality in timely fashion to allow the DLCC to begin planning with a high quality and comprehensive international data set on fishes that is unparalleled for most other taxa found in the DLCC.

Proposed projected future species distribution models (SDMs) will identify areas of conservation and restoration priority. Thus, the completed analysis will produce management options for the Desert LCC that can support on-the-ground agency management decisions at regional and landscape scales. As such, this work extends and complements our past Great Plains Landscape Conservation Cooperative (GPLCC) work [3]. While the results of this project will only involve fishes, the methodology developed is generalizable to all other taxa (and other geographic regions). The methodology will be implemented as a decision support tool for GIS platforms and will draw on our previous experience in developing software tools and websites to aid conservation and restoration decisions.

(c) Describe and discuss in detail the stages of the proposed project.
The methodology for this project consists of biodiversity data provision and curation, and the application of a maximum entropy algorithm (incorporated in the Maxent software package [4]) using biological data and the climate layers generated by large-scale international efforts to model climate change. See below for expanded explanation of each project stage including dates, methodology, and expected degree of success for each task.

Data acquisition and processing (1 Sept., 2011 – 30 Sept., 2012)
Fish occurrence data for the Texas portion of the DLCC are already available from the PI's Fishes of Texas Project (FoTX; [1]) maintained and housed at University of Texas' Texas Natural Science Center (TNSC). The FoTX Project has been the focus of several members of this research group for 6 years and we now consider ourselves experts in museum occurrence data management and improvement. This database endows us with a comprehensive highly normalized and verified fish occurrence database for Texas. It has been compiled from vouchered specimens of all freshwater species known from Texas maintained at 42 institutions and includes over 80,000 precisely georeferenced records from the entire history of collecting in Texas from the mid 1800's to present representing approximately 7,500 localities. Its rigorous quality control has permitted the construction of high–quality, accurate species distribution models (SDMs) for Texas species (see below in Technical Project Description section "e" and Figure 4 for an example SDM for a threatened Texas fish produced using FoTX data). The comprehensively documented FoTX project web site (http://www.fishesoftexas.org) can be consulted for more detailed information about the project and its methods.

Data from the Texas portion of the DLCC can easily be queried from the FoTX website and will represent a significant contribution to the final product from this study. There are 7,155 records (=museum lots) from the DLCC area in the FoTX database representing 98

species contributed by 29 institutions. These data will be included in addition to the comprehensive data set we propose to compile and improve below.

We propose to apply our FoTX data management and editing methodology to the Río Grande drainage subset of our acquired data set. Thus all Río Grande records will be extensively improved much like we have done for the FoTX project data. We will retain and organize the verbatim donor data to fit into the structure of the FoTX database, format dates into separate fields (year, month, day), georeference localities (also providing error estimates), synonymize all verbatim taxa names to an accepted taxonomy [5], and plot out species distribution maps to facilitate flagging of records that are geographic outliers and in some cases temporal outliers. Flagging records and producing georeferencing error estimates will permit us to exclude dubious records from SDM's.

Our comprehensive data search will include the entire DLCC area plus the entirety of the Rio Grande basin, and will exclude the Gila and Colorado River drainages (Figure 1). All fish occurrence data in this area will be databased and delivered as part of this project. We will rely primarily on GBIF, Fishnet2 and the Museum of Southwestern Biology at University of New Mexico (see support letter) for data from New Mexico and are confident that the results will be impressive for that well sampled state. We have also obtained the Mexican portion of the SONFISHES database [6] from Dr. Peter Unmack who agreed to let us use it for this project. SONFISHES is a FoTX-like project focused on the Lower Colorado, Gila and Yaqui rivers in Arizona, New Mexico, Sonora, Sinaloa and Chihuahua [7,6]. The FoTX database, which currently contains some Mexican occurrence records that will be used in this project, can be easily mined, but its Mexican records except for those on the Río Grande mainstream, were not systematically acquired, nor have they been fully processed as have all Texas records. We also have a recent download of data provided to the PI by the University of Michigan (UMMZ - a very important collection for Mexican fishes [8]) which is not available online. We also will query all of our 42 existing FoTX data donors for data they may have in the study area.

Compilation and summarization of a preliminary version of the database that we propose to compile for this project was done to demonstrate both the feasibility and values of providing such a data set and to determine the resources required to do the proposed work and coordinate it among team members. This search was preliminary only (lacking queries to our FoTX data donors and Mexican data we expect to receive from UNM) and will be executed more thoroughly if funded, by querying more sources, albeit ones less-likely to have large relevant data caches, but which almost certainly will add important records. We believe our preliminary database has captured approximately 85-90% of all existing data on freshwater fishes in our study area. Many of the data summary statistics throughout this proposal were derived via this exercise and were difficult to acquire and summarize due to much-needed data improvements (re-formatting, standardization and editing) and reflect an under-approximation of what we expect to produce if this project is fully funded.
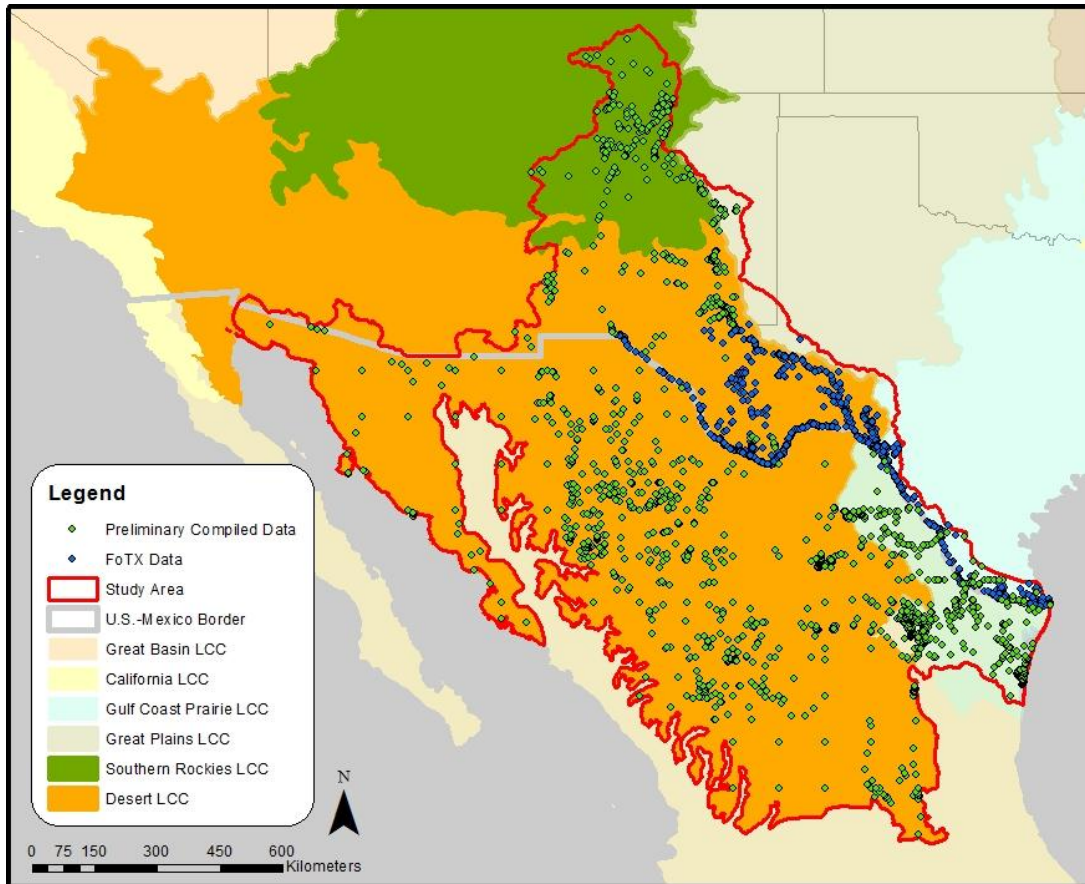
Figure 2. Spatial distribution of georeferenced localities in our preliminary data set analysis (GBIF, FishNet2, SONFISHES, UMMZ) and FoTX data within the study area of this proposed project. Note that many of these, despite having associated coordinates, require more precise georeferenceing with error estimation for development of accurate niche models. Additionally, preliminary data displayed represents approximately 60% of that acquired; the remaining data lack coordinates.

Our preliminary data set has 32,527 unique occurrence records derived from 61 original data sources represented by the following codons: AM, AMNH, ANSP, ARC, ASU, AZGF, BYUH, CMN, CSIRO, CU, DGR, ENMU, FCB-UANL, FMNH, GNM, HU, IBUNAM, ICM-CSIC, JFBM, KU, LACM, MCNB, MCZ, MNCN, MNHN, MSB, MSU, MSUM, MZS, NCSM, NRM, OKMNH, OSUS, PBDB, RMNH, ROM, SAMA, SBMNH, SIO, SMF, SMNS, SU, TCWC, TNHC, TU, UA, UANL, UAZ, UCM, UCZM, UMMZ, UMZC, UNM, USNM, UWFC, WNMU, YPM, ZMA, ZMH, ZMUC, ZSM (see [9] for codon translations). There are 140 taxa among the combined records – a number which is inflated by complex taxonomic synonymization issues impossible to address at this preliminary and unfunded stage in our exploration of this proposed work. Approximately 60% of the records have been georeferenced by their owners using mostly unspecified methodologies. Since we have determined that many of these already georeferenced localities are not as precisely placed as we propose is necessary for the kinds of applications we propose here, and many are clearly erroneously places, we propose here to verify and correct all records using standard methodologies used by the FoTX project [1]. Despite these inaccuracies, we display the approximate spatial coverage of the 20,787 records in this preliminary data set that have coordinates by

plotting them in Figure 2. The temporal coverage of the preliminary data set is large ranging from 1852 to 2007 (median = 1975) and is summarized in Figure 3.

Specifically we propose to perform the following tasks:

1. Compile all available data (sources described above) for the study area - the entire area of the DLCC exclusive of the Colorado/Gila basin and the entire Río Grande basin (Figure 1).
2. Isolate and retain all verbatim data as received so that it can be conserved and made available together with normalized versions of it in the final data set.
3. Normalize all acquired data into the format of the FoTX project (Specify 6.2 or more recent data schema: [1]). Complete details in FoTX project documentation (www.fishesoftexas.org).
   a. USGS and INEGI place name standards will be used for State/Estado and County/Municipio (if available in the acquired data). We will create new database fields for this purpose.
   b. All taxonomy (species and higher) will be brought into compliance with the Catalog of Fishes [10] and AFS Common Names [5] standards. Not complete synonymization as below for Río Grande records.
   c. Dates will be transformed to a single standard date format, as well as copied to separate year, month, and day fields.
4. Isolate all Río Grande basin records for further processing:
   a. Since preliminary data searches indicate that approximately 40% of all locality records lack geographic coordinates and nearly all lack indication of river basin, all data from all states that intersect the Río Grande basin will be subjected to a meticulous preliminary computerized analysis (e.g. automated georeferencing, containing place names known to be in or near the Río Grande basin) and manual review by project staff to select all records that fall within the Río Grande:
      i. Georeference with precision estimates following FoTX procedures. All records will include detailed descriptions of specific methods used in georeferencing.
      ii. Normalize locality descriptions (see [1]) - INEGI place name standards in México and USGS in US. All measurements converted to metric units. (see [1])
      iii. All locality descriptions in Spanish will be translated to English (retaining verbatim original description)
      iv. Using GIS, assign all records to higher geography and geopolitical categorical units (e.g. ecoregions, drainages, etc.) to facilitate queries outside of GIS
   b. Synonymize all recognizable taxa to currently accepted names. This will include correcting historical names with currently accepted names [5] and correcting names for some species whose names can be confidently changed based on published literature.
   c. For all Río Grande species, search for and correct or accept geographic outliers (inspect specimens as possible). Flag as possibly incorrect all

occurrence records for which species identification or geographic placement questions remain.
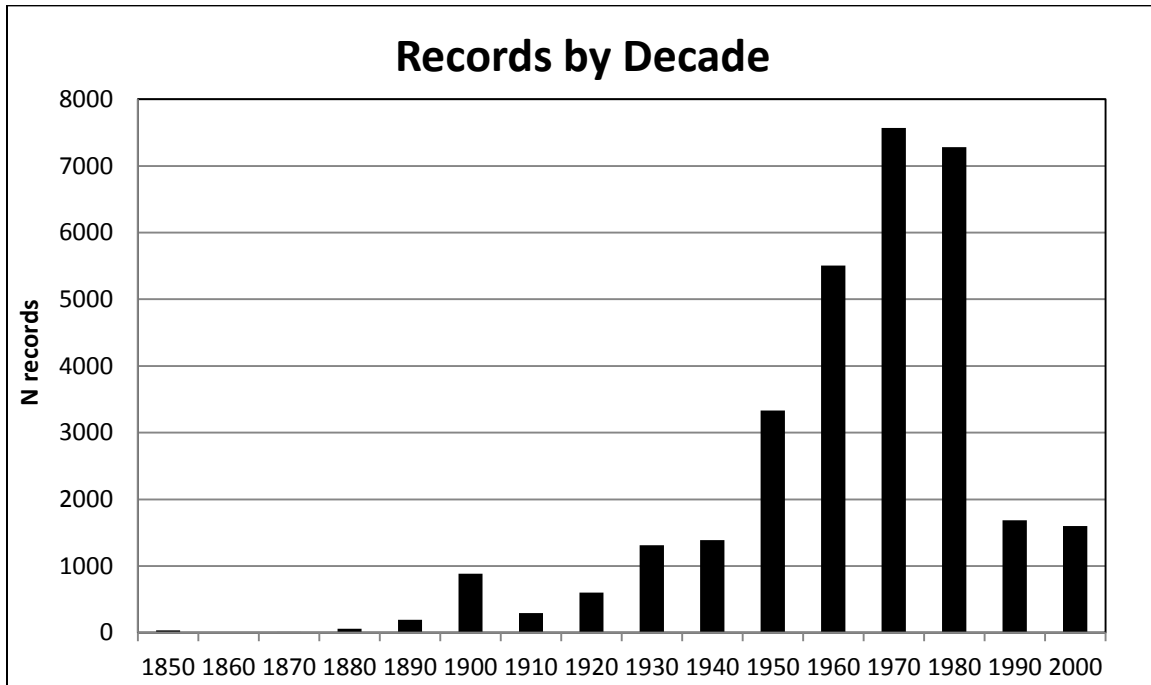
Figure 3. Histogram showing temporal distribution of records in our preliminary data set. Data suggest a dramatic decline in new fish collections being made in the study area since the 1980's.

Species Distribution Models (1 Oct., 2012 –30 Mar., 2012)

Near the end of the preceeding data processing phase of the project, data will be in adequate condition to allow us to determine what species we have adequate data to construct SDMs. We will consider modeling all priority species within the Río Grande (see Appendix 1), but our ability to do so for some of the rarer species may be limited by the number of records in the finalized data set. A minimum of 10 records is needed for model construction [11]. Species Distribution Modeling thus will begin by Oct 1, 2012 and extend over the next 6 or 7 months.

Species distribution models predict the potential geographic distribution of a species based on occurrence points of a species and predictive environmental variables; they are sometimes interpreted as approximating the ecological niche for that species [12]. The SDM construction protocol that will be used has been previously used by the Co-PI's laboratory in over a dozen studies (most recently [13-18]). Since this protocol has recently been published [18], the description here will be cursory.

A wide variety of machine–learning algorithms have been used for SDM construction (reviewed in [20]). In the context of biodiversity conservation, genetic [12,21] and maximum entropy algorithms [22,23] have been most widely used. This project will use a maximum entropy algorithm incorporated in the Maxent software package [4,24] because it directly provides probabilistic output (unlike the genetic algorithm of GARP [25]) that can be used without further treatment for subsequent analyses, and because a variety of recent studies have concluded that its performance is superior to those of other methods

[11,20]. Standard settings [18] will be used to initiate model runs. Model performance will be internally evaluated using the AUC, that is, the area under the repeater–operating characteristic curve (ROC) [24].

The species distribution models (SDMs) used for this project require as input high quality species occurrence data (georeferenced data points) such as the above steps will produce, and environmental data layers which form the explanatory variables. All required environmental datasets are currently in our possession; see current status in Technical Project Description section "e" for a description of future climate layer construction. Specifically we will use subsets of the 19 bioclimatic layers from the WorldClim database (www.wordclim.org; [26]) and four topographic variables: elevation, slope, aspect, and the compound topographic index (CTI). Elevation is available from the United States Geological Survey's Hydro-1K DEM dataset (eros.usgs.gov/#/Find Data Products and Data Available/gtopo30/hydro). Slope, aspect, and compound topographical index will be derived from the DEM using software tools (viz., the Spatial Analyst extension of ArcMap 9.3). All these data layers are available at 0.05 degree resolution. Given that the environmental layers to be used for SDM construction in this project are largely restricted to the post–1950 period, only species' distributional data from after 1950 will be used for model construction.
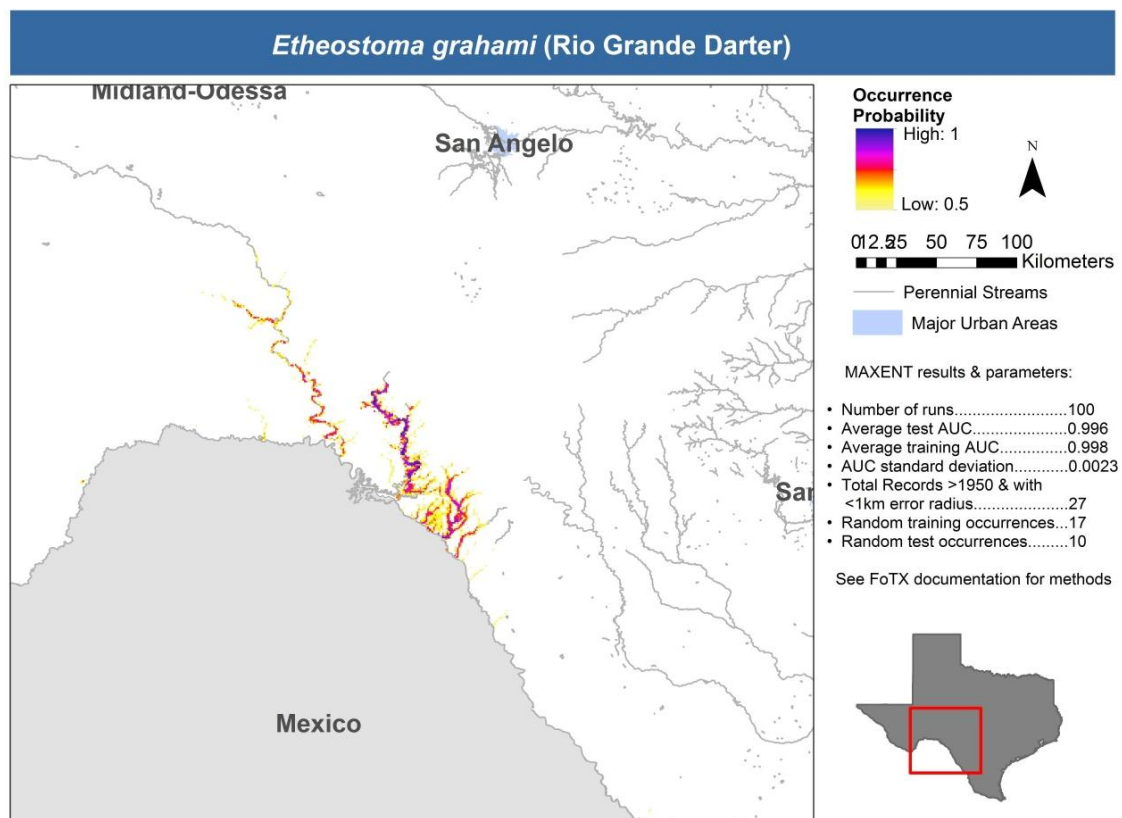
Figure 4. SDM of *Etheostoma grahami* (Río Grande Darter, G2G3 – TXS2) using FoTX data. Methodology of model construction is summarized in Technical Project Description section "e". The model is displayed as a symbolized raster layered over a shapefile of perennial streams. Only modeled probabilities > 0.5 are shown to illustrate what we suggest be interpreted as prime suitable habitat range within Texas.

Climate Change Projections (1 Apr., 2012 – 30 Jun., 2013)

We will project selected fish SDMs using climate change models based on emission scenarios A2 (extreme), A1B (intermediate), and B2 (conservative), created in our lab from the latest IPCC fourth assessment (see Technical Project Description section "e" below for details). The best SDMs will be used to predict future distributions for A2, A1B, and B2 scenarios to establish robust results in the face of uncertainty. This methodology was recently used by co-PI Sarkar [22] and others [12] to predict range shifts of insect disease vectors in the face of climate change, and is adopted here for use in a more general context. We will create high resolution projections for 2020s, 2050s, and 2090s. We will use climate data at a scale such that projections will be at a 0.05 degree resolution. Future environmental variables, for the extent of the focal species' ranges modeled, will be provided in raster format, useful in diverse GIS analyses. Future projections will likewise be provided in raster format as well as images useful for visual inspection and comparative analysis. See Figures 5 and 6 for examples of these types of products, which are explained in Technical Project Description section "e".
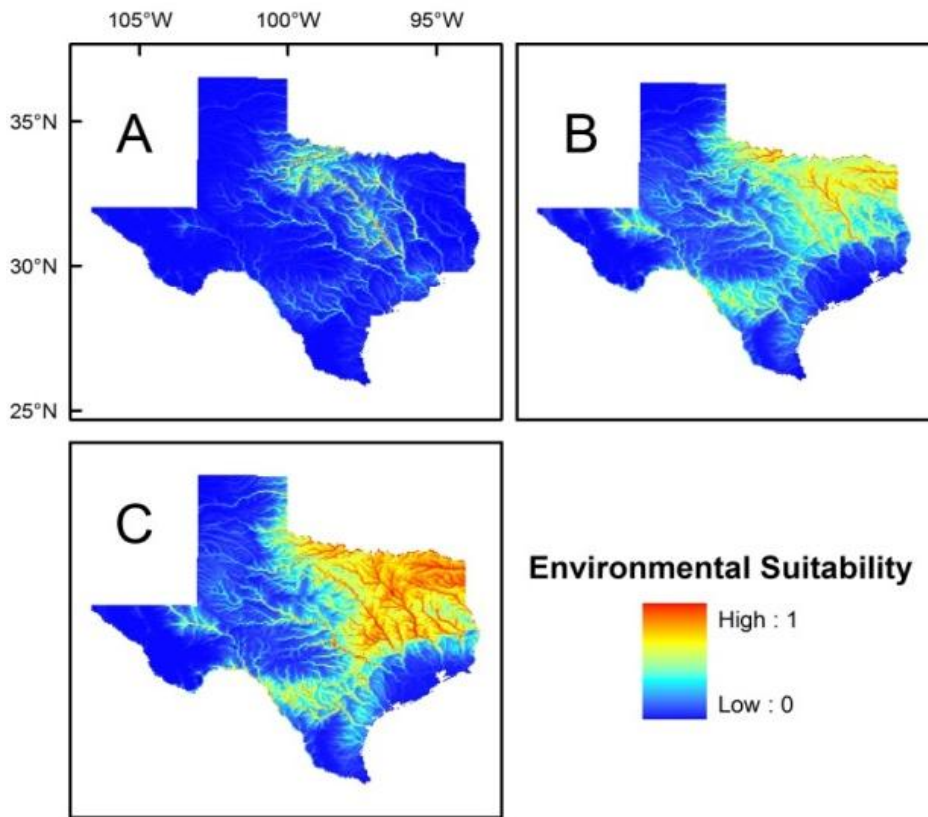
Figure 5. Current (A) and Future projections ([B – B1emission scenario]; [C – A2emission scenario]) for *Notropis oxyrhynchus*, Sharpnose Shiner.
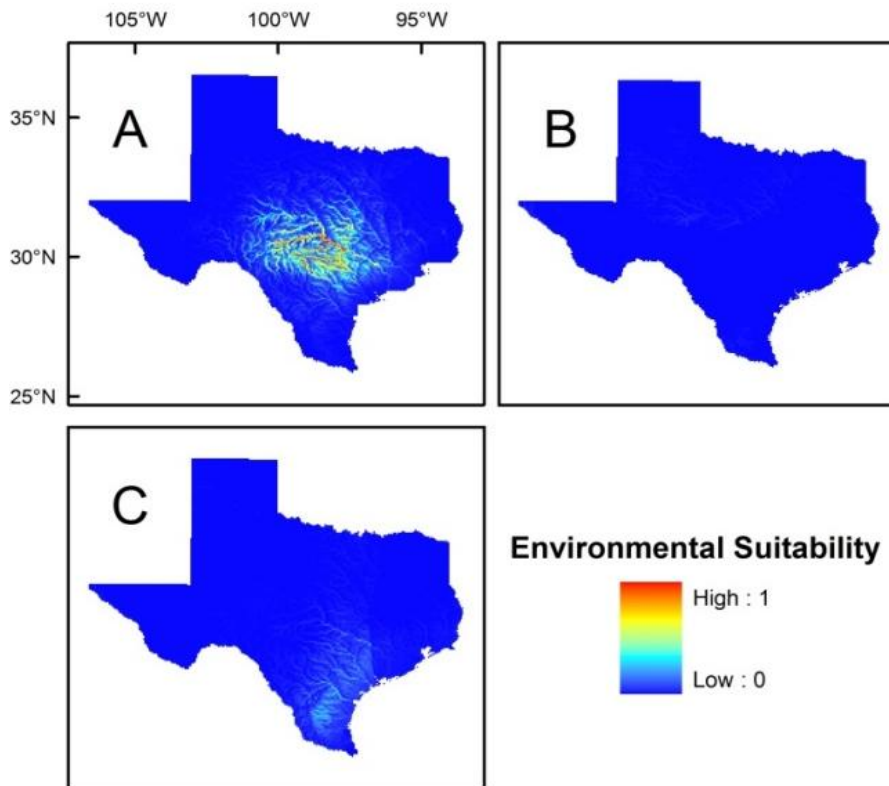
Figure 6. Current (A) and Future projections ([B – B1emission scenario]; [C – A2emission scenario]) for *Micropterus treculii*, Guadalupe Bass.

Interpret results, produce manuscripts, present results at meetings, deliver final report and products (1 July, 2013 – 31 Aug., 2013)
See section "c. Dissemination of Results" elaboration on dissemination of products.

(d) Provide a specific discussion of the any anticipated problems or major difficulties in performing or accomplishing the work.
The modeling portion of this project involves an innovative systematic extension of modeling techniques developed by this group to a new geographical region and taxa. However, we have already had some preliminary results from such an extension as part of our GPLCC project during which some minor problems were resolved [3]. No further difficulty is anticipated on these grounds. However, our past experience with the GPLCC analysis indicated that future projected climatic conditions often have no overlap with present conditions across species distributions and are sometimes disconnected by large segments of unsuitable habitats. Whether such range shifts are possible, precluded because of poor dispersal capacities, or unnecessary because of phenotypic plasticity, remains unknown. These uncertainties must be addressed as the work proceeds. Using a variety of models will augment the robustness and reliability of results that are common to all of them.

(e) Describe any prior studies that relate to the project or which will inform the project.

Hendrickson's long and extensive experience collecting fishes and conducting research throughout the Mexican and U.S. portions of the DLCC, having collected fishes from, and published about the fishes and habitats of, every major drainage of the DLCC [27-37] will certainly inform the project, as will his (and his assistants') extensive experience with museum specimen-based data compilation and processing (e.g. the FoTX project). Data collection for fish species of Texas is at an advanced stage due to work by the PI and FoTX project staff. That project's extensive quality control has permitted the construction of high–quality, accurate species distribution models (SDMs) within the state of Texas. So far, 128 SDMs have been constructed. All 128 species models had an average AUC > 0.89, 124 had an AUC > 0.90 (min. = 0.89; max. = 1.00; ave. = 0.97), well above the generally accepted requirement of AUC > 0.6. [38,39]. See figure 4 for an example of one of these models.

Using select datasets already available to us in appropriate formats, we offered the GPLCC new analyses, data compilations and normalization, and new original decision support tools, such as these projections, produced from our data to extend usefulness of our data resources to GPLCC resource managers. The GPLCC grant [3] provided a demonstration of projecting current climatic envelopes onto future climate scenarios for a select group of fishes. Future Climate layer construction included using the latest IPCC, http://www.ipcc.ch/) Data Distribution Centre (http://www.ipcc-data.org/obs/cru_ts2_1.html) datasets, including past monthly average, maximum, and minimum temperature and precipitation layers from the Climate Research Unit (CRU) high resolution climate data, version 2.1. Future climate global circulation models (GCM) from the IPCC 4th assessment were downloaded from the World Climate Research Programme's (WCRP's) Coupled Model Intercomparison Project (CMIP3) Multi-Model Dataset Archive at the Program for Climate Model Diagnosis and Intercomparison (PCMDI) (http://www-pcmdi.llnl.gov/ipcc/_about_ipcc.php). These future scenarios and models encompass the conservative (B1) and extreme (A2) projected emission scenarios expected this century. Climate layers were averaged for each decade, 2001-2100 for future data. Using the Computational Information Systems Laboratory's (CISL's) National Center for Atmospheric Research (NCAR) Command Language, each decadal layer (i.e. average, minimum, and maximum temperature and precipitation) was linearly interpolated and corrected for elevation (6.5 °C per 1000 meters), using the Global 30 arc-second Elevation Dataset (GTOPO30), to 0.05 degree resolutions. Nineteen bioclimatic layers, corresponding to the standard WorldClim (http://www.worldclim.org/) layers most commonly used in species distribution modeling, were created from the interpolated data. Figures 5 and 6 demonstrate a characteristic and extreme species response to projected future conditions, respectively.

(f) Identify sources and support for non-Federal funding.

The university has agreed to waive indirect costs for this project and the waived charge that would normally be charged to the BoR for this project is included as part of the required cost share. Additional cost share is provided by the university's commitment of 1 month of the full time of each Hendrickson and Sarkar to this project in each of the two years of the project.

(3) Technical Proposal: Project Evaluation Criteria.

(a) Technical Merit

Subcriterion No. 1—Project Scope:

Under which Research Area(s) A-C does the proposal most closely apply.
This proposal addresses Project Task Areas A, B and C. Under Project Task Area A, it specifically addresses "e. Projecting natural system responses to changes in climate and hydrology.". Under Project Task Area B it specifically addresses "b. projecting changes in the distribution and populations of fish and wildlife that are dependent on large rivers and permanent streams.", "c. Projecting changes in distribution of invasive aquatic species…", and "f. Projecting changes to endangered species habitat distribution that may affect water releases and habitat improvement projects." Under Project Task Area C it specifically addresses "a. Assessing how the projected changes identified within the previous task area and associated water resources policy changes may impact the management of natural or cultural resources."

What is the primary objective (question to be answered) of the proposed project? Articulate how the primary objective directly ties to the task area(s) identified?
Primary objective/question: What are the distributional patterns of cross-border fishes relevant to the DLCC, and how will climate change impact the conservation and restoration of inland fish species within Río Grande Basin.

Under task area:

A. **subsection e:** this project projects fish species' responses to changes in climate.
B. **subsection b:** this project projects changes in distribution of fishes that depend on large rivers and permanent streams.
    subsection c: this project projects changes in distribution of invasive fish species in response to climate change.
    subsection f: this project projects changes to endangered species distributions in response to climate change, which may affect habitat improvement projects.
C. **subsection a:** this project assesses how changes identified within previous task areas (native, endangered, and invasive fish distributional changes due to climate change) may impact the management of natural resources.

What are the specific tasks that will be undertaken to answer the research question?
As described above in detail, the tasks undertaken to answer the questions are:

o Compile a high quality, comprehensive, and authoritative dataset of fishes for a large geographic extent relevant to the DLCC.
o Construct Species Distribution Models for priority and invasive freshwater fishes.
o Project species models onto a range of future climate scenarios.

13

Subcriterion No. A2—Ability to Accomplish Scope:

a. Describe the project team's ability to accomplish the project scope by including:

How will the budget be allocated to each of the tasks identified?

As this proposal is computationally intensive in all tasks, the budget will go primarily towards salaries of research associates delegated to data compilation and management as well as basic georeferencing. Some computational equipment is required to handle the intensive GIS work with the large data set that will be produced. See Budget Proposal section at the end of this document for specifics of allocation.

Who are the members of the project team, and what tasks will each member perform?

P.I. Dr. Dean Hendrickson – *Qualifications:* 35 years of work in natural history collections, 20 as Curator of Ichthyology at University of Texas at Austin's (UT) Texas Natural History Collection (TNHC) where he made that fish collection the first in the world to be fully searchable in its entirety on the Internet (via Gopher in 1993) and assured its continual availability to present via custom websites, FishNet, GBIF, etc. PI of FoTX Project (above). Long history of training and field research in aquatic systems in South America, Europe, Australia, México, Texas, and SW US, focusing on fishes and conservation. 80 peer-reviewed publications, including work and publications on all drainages of the DLCC's border states in México [27-37]. Fluent in Spanish, he has collaborated extensively with many Mexican ichthyologists and is a founding member of the Mexican Ichthyological Society (SIMAC - http://www.sociedadictiologicamexicana.com/). He established, and is currently Director of, a field research station in Cuatrociénegas, an important federally protected area in the Chihuahuan Desert within the DLCC. Staff and students currently working with Hendrickson to contribute to this proposed project have extensive experience in all aspects of collection of fishes and management of associated data from the field through identifications and working with complex collections databases, SDMs and GIS. It is anticipated that current, experienced FoTX project staff will continue to work on this project if funded. *Roles and Responsibilities*: Overall project coordination and supervision of the three project staff at UT proposed to be hired for this project; supervision of production of products from FoTX database and other datasets (e.g. data outputs, models); assure timely delivery of all project deliverables.

Co.-P.I. Dr. Sahotra Sarkar – *Qualifications:* 20 years of experience in ecological modeling and computational biology; 10 years in ecological field research in TX and Mexico. Developed software decision support tools for biodiversity conservation (ResNet, Surrogacy, MultCSync, ConsNet—see www.consnet.org) used in > 30 countries. Coordinator for National Center for Ecological Analysis and Synthesis Working Group on Complex Environmental Decisions. Author of six books, including *Systematic Conservation Planning* [40] and over eighty refereed journal articles in ecology and conservation biology. Graduate students and other research assistants in Sarkar's lab working on this project are experienced in SDM construction, use of such output both in forecasting impacts of climate change, and prioritizing areas for

conservation and restoration action, and systematic conservation and restoration planning. ***Roles and Responsibilities:*** Supervision of the development and tests of species distribution models; modeling distributional changes expected due to climate change, and conservation and restoration prioritization. Development and extension of all software decision support tools for this project will be performed in Sarkar's lab.

Three assistants will be hired. If contracting is completed within approximately 1-2 months of the anticipated start date it is most likely that Adam E. Cohen, Ben Labay and Melissa Casares, all currently employed under Hendrickson's supervision in the Fishes of Texas Project, will most likely still be available and able to begin work on this new project. Each has extensive experience working in the same capacities as they are here proposed to do for this project. If they are not available, replacement staff are available and will be quickly hired from the large pool of candidates with appropriate skills at University of Texas.

What are the credentials of each of the project team members?
Dr. Dean Hendrickson - B.S. Fisheries/Wildlife Management, 1973, Arizona State University (ASU), Tempe, Arizona.
M.Sc. Applied Hydrobiology, 1977, University of London, London, England
Ph.D. Zoology, May, 1987, Arizona State University

Dr. Sahotra Sarkar - B.A. Mathematics, Philosophy, and Physics. 1981. Columbia University, New York City, New York.
M.A. Conceptual Foundations of Science. 1984. University of Chicago, Chicago.
Ph.D. Philosophy. 1989. University of Chicago, Chicago.

Have the project team members accomplished projects similar in scope to that proposed in the past either as Principal Investigators or team members?
Yes, the PIs are long-time colleagues from the University of Texas at Austin that collaborated to help provide information and products to the Great Plains LCC while at the same time furthering our own highly complementary research and institutional collections improvement and management goals. Both have partnered in many ways for many years, and have productive, continuing working relationships with state and federal agencies throughout the region covered by this project, including Mexico.

Is the project team capable of proceeding with tasks within the proposed project immediately upon entering into a financial assistance agreement?
Yes. If the contract is signed by the proposed start data or shortly after, the University will be able to advance funding to the project. That would allow current employees who will still be employed on other projects for which contractual obligations will have by then be completely met to have their appointments extended to begin work immediately on this project.

b. Relevance of the Project to the LCC:

What is the geographic extent of the project? What is the relevance of the results of the project to a broader geographic area?

The geographic extent of the proposed study area totals 1,646,900 km^2 that includes 75% of the total area of the DLCC (all of it to the east and south of the Colorado and Gila river basins), as well as the entire extent of the Río Grande basin, some of which is outside of the DLCC, but the study area includes 21% of the total area of the Southern Rockies LCC, 25% of the Gulf Coast Prairie LCC, and 3% of the Great Plains LCC. The broader area is relevant for studies of fishes, since they are constrained by hydrologic, not sociopolitical boundaries such as those delimiting countries, states or LCC's. All LCCs mentioned above will benefit from this project in the same ways the DLCC will benefit.

Does the project complement existing efforts within the geographic area of the LCC

As pointed out in part in the FOA, the drainages that are included in the DLCC but excluded from this study, the Colorado and Gila, have been very well studied and continue to have high levels of research on aquatic systems, and particularly fishes [7,6,41-43]. Compared to those, all of the other, primarily Mexican drainages included in this study have been grossly understudied, though the Yaqui stands out as one Mexican drainage that is relatively well studied [7,36,44,45], in large part by the PI and his colleagues. We are unaware of programs that continue work today on Yaqui fishes, though the PI has published recently on one of its priority species [46] and a large sustainability project on the river and its relationship to agriculture has examined hydrology, climate and other sustainability issues very thoroughly (http://yaquivalley.stanford.edu/). Much of the primary literature on the Concepción [29] and Sonoyta [31] river basins comes from the PIs own research and we are not aware of ongoing programs in those small basins other than management conducted by Mexican workers associated with the Pinacate Reserve and NPS at Organ Pipe National Park. The Casas Grandes in Mexico is similar – relatively little prior work [47,48] and we are unaware of ongoing projects on fishes. Currently, most Mexican drainages have low levels, if any, research activity, though some have government water management programs in place (e.g. Conchos), but in general their fish faunas remain poorly known. The Río Grande, while being highly managed, and having relatively high levels of research and management programs for fishes (e.g. silvery minnow), has had most of its fish research and management activity restricted almost entirely to the US or the mainstream along the border [49-51]. Its fish fauna in Mexico is by no means well known and this project will help immensely in that regard. Fishes of major Mexican tributaries, extremely important as the major source of water for the Río Grande along most of the international boundary, are particularly poorly studied. Existing published work has been restricted largely to easily accessed lower elevations [52,53] and only recently have remote higher elevations begun to be explored, resulting in surprising discoveries by the lead PI and collaborators of two new native trouts [52,53]. We know of no efforts outside of this proposal to systematically and comprehensively compile and analyze basin-wide fish occurrence data for the Río Grande basin, let alone any efforts that are trying to model fish distributions in the region and analyze the effects of climate change on them.

What is the expected benefit of the proposed project to partners within the LCC?

The raw occurrence data provided are an indispensable foundational resource for diverse on-the-ground work on landscape-level aquatic biodiversity sustainability. Partners within the LCC will be able to leverage this proposal's efforts to provide these standardized and quality-controlled occurrence data. Additionally, this proposal specifically addresses the LCCs landscape-level approach and principal function of providing scientific and technical expertise to produce landscape-scale conservation designs. It will aid in the core capacities of i) biological, ecological, and physical sciences, ii.) population, climate, and landscape modeling, statistical design and analysis, iii). development of resource inventories, and management evaluation protocols, iv.) web-hosting, database design and management, v.) resource planning and conservation design, and vi.) spatial data acquisition and analysis. This proposal specifically addresses the need for procurement of geospatial tools to direct management decisions in the face of uncertainty due to community regime shifts, climate change, and extinction debts. This project will build on work performed for the GPLCC, expanding the geographic and taxonomic scope to include much of the DLCC.

- **Explain how the proposed project will help address specific resource management issues within the LCC, including:**
  - **Will the proposed project benefit water management within the LCC? Will it benefit the management of other natural or cultural resources? Explain how.**

The history and current status of fishes within the Yaqui River provides a specific example for how the products proposed here would enhance management of natural resources within the Desert LCC. The Yaqui River is now one of the more-studied of the northern Mexico rivers [7,36] since its tributary draining the southeast corner of Arizona was once home to 7 native fishes, all (Appendix 1) now of great conservation concern and one nearly extinct (*I. pricei*) [46]. Five persist there; but one (Yaqui catfish) only by reintroduction. All Yaqui species once known from Arizona are still found, but are increasingly rare, in Mexico. A recent and careful comparison of the history and current status of the Yaqui's fish fauna with the very thoroughly documented history of demise of the closely related and now highly imperiled Gila River fish fauna concluded that the Yaqui's native fishes are clearly on the same trajectory toward endangerment or extinction of natives and replacement by non-natives, but that the Yaqui fauna is lagged about 4-5 decades behind the Gila River fish fauna [7] on this trend. Such conclusions were only possible by laborious compilation and rigorous analysis of fish occurrence records for the Gila and Yaqui as we propose to do for the rest of the entire Mexican portion of the DLCC. For the Río Grande basin we will perform analyses that will allow generalizations about the relatively health of the Río Grande fauna similar to those of Unmack and Fagan 2004 [7], thus providing a much more useful vision of what the future holds for all that basin's internationally shared species than has ever been possible before.

If we are to effectively manage for the persistence of U.S. populations of imperiled fishes in drainages such as the Yaqui, and proactively manage resources there to prevent the Yaqui experiencing the fate of the Gila River, it will require persistence of Mexican

populations and ideally natural gene flow via re-connection of US populations with their nearby downstream neighbors. Historic occurrence data for endangered taxa within the Yaqui, such as proposed to be produced in this project, provides fundamental and critical historic baseline habitat associations from which effective species distributions models are built and by which resource managers can leverage for effective restoration and repatriation efforts. In a parallel situation a bit further East, *Gila nigrescens* exists in the US only as a very small population in the Mimbres River in New Mexico, but a few other very small, isolated and threatened populations are still found elsewhere in the Casas Grandes drainage complex in Mexico. In this now fragmented, formerly much larger drainage it has clearly been hundreds if not thousands of years since these populations were connected, but almost surely the greater genetic variation of the combined populations will prove important to future management efforts for these small, highly fragmented populations.

- o **Will the results inform resource management actions immediately upon completion of the proposed project or will additional work be required?**

The results of this proposal can be immediately implemented in decision support regarding selection of a species' prime suitable habitat that is a candidate for restoration or repatriation. Whereas most Mexican fish occurrences are currently buried in relatively inaccessible places, or at least in less than ideal condition for easy summary and use in GIS, we will make them quickly easily accessible in a single, highly normalized GIS-compatible database. Additionally, our modeling products will immediately depict how imperiled fish species may be affected by changing climates and what habitats may be climatically suitable for them in the future.

- o **Is there support for the proposed project from resource managers or other partners within the LCC (identify any partners or letters of support).**

Time constraints and space limitations impeded our ability to document support for this project via letters, two are included here, from Nathan Allen (USFWS) and Dr. Thomas Turner, University of New Mexico.

c. Dissemination of Results:

If spatially explicit data or tools are being developed, describe how this information will be made available to Geographic Information System platforms and provided to partners within the LCC.
Biodiversity data compiled through this project will be provided in a Microsoft Excel file (or other format if requested). We also intend to serve these data through our publicly accessible FoTX project website, where they will be interactively searchable and downloadable via our existing interface. This interface was designed specifically for Texas records, thus the full functionality of the FoTX website will not be available for viewing and querying data from outside of Texas. The FoTX website documentation will be edited to provide explicit instructions for querying the data from this project. Environmental layers constructed to build species distribution models will similarly be made available, but via a separate UT server. All research protocols and analysis methods will be made publicly available through publication and via personal requests to the

investigators. Future environmental variables for the extent of the focal species' ranges modeled will be provided in raster format, useful in diverse GIS analyses. Current and future projections will likewise be provided in raster format as well as images useful for visual inspection and comparative analysis.

Once the project is complete and data donors can see the results, as has been the policy of the FoTX project, we will provide the copies of their data incorporating revisions/corrections/georeferencing, etc. done by this project in hopes that they update their original copies of the data to reflect our changes. Also, if they agree and the DLCC wishes, we will serve our copies of their revised data to GBIF or other major biodiversity data provider via one of the university's servers.

Describe the anticipated number and type of peer reviewed scientific journal articles.

We expect to produce a minimum of 2 peer-reviewed papers, specifically one on modeling and conservation planning for priority fishes in the Río Grande basin, and another covering conservation planning that incorporates projected species responses to climate change. We are also exploring use of our models to derive innovative measures of biological integrity (see [54]), and the dataset developed as part of this project could be useful in that independent research and provide additional publications.

Describe the number and type of presentations regarding the results of the project. For example, presentations at scientific conferences or presentations to resource managers within the LCC.

Results will be disseminated through: (i) regional and national scientific seminars, including some (but not all) meetings of the American Fisheries Society, American Society of Ichthyologists and Herpetologists, Desert Fishes Council, Society for Conservation Biology, Ecological Society of America, and Southwestern Association of Naturalists; (ii) presentations to local and state agencies, including TPWD and potentially other venues of interest to the DLCC. All products of the project including datasets, models, software, and planning protocols will be made freely available through a UT institutionally supported web-site.

d. Connection to Reclamation Project Activities:

o How is the project connected to Reclamation project activities?

All environmental assessments and impact statements being conducted or to be conducted by reclamation offices will benefit from the proposed project as it will enhance capacity to environmentally assess aquatic communities, and propose management solutions, from the perspectives of natural system response induced by climate change at landscape scales. For example, analyses done to date (see Current Status in Technical Proposal Description section "e", and Figure 6) are being utilized in parts of Central Texas to guide management decisions by Texas Parks and Wildlife Staff with regards to habitat restoration for the Guadalupe Bass, *Micropterus treculii*, an endemic game fish as well as a species of concern for the State of Texas.

- **Does the applicant receive Reclamation project water?** -No

- **Is the project on Reclamation project lands or involving Reclamation facilities? –** The proposed study area covers parts of 3 BoR regions: The Great Plains, Upper Colorado, and Lower Colorado Regions.
- **Is the project in the same basin as a Reclamation project or activity? –** Reclamation has projects in the Río Grande basin.
- **Will the proposed work contribute water to a basin where a Reclamation project is located? -** No, the proposed work does not directly influence water supply.

Performance Measure for quantifying post-project benefits

To assist LCC staff with this reporting requirement we will quantify project benefits on the basis of numbers of occurrence records provided and made available online, perhaps separated by categories based on priority species and/or by LCC. Other quantifiable measures easily provided would be numbers of records fully or partially normalized for specific database fields, number georeferenced, number flagged as suspect, number with varying georeference precision radii, etc. Since the products will also include environmental layers (with metadata) used in modeling and models (also with complete metadata), those too could be quantified and categorized (e.g. how many species were forecast to experience strong shifts of climate-based habitat preferences vs. how many not). We will also report on progress with publication and dissemination of results. The output of this project will be easily quantifiable in many ways and we are happy to work with LCC staff to provide whatever summaries they desire for reporting purposes.

Evironmental and Regulatory Compliance

(1) Will the project impact the surrounding environment (e.g., soil [dust], air, water [quality and quantity], animal habitat)?
All activities deal with data already collected. No fieldwork is included in this study.

(2) Are you aware of any endangered or threatened species in the project area? If so, would they be affected by any activities associated with the proposed project?
Endangered species in the geographic area of this study will be affected only positively, via the increased knowledge of their distributions and biology that will be provided, and applications of that knowledge for improved management.

(3) Are there wetlands inside the project boundaries? If so, please estimate how many acres of wetlands there are and describe any impact the project will have on the wetlands.
There will be no direct impacts on wetlands as there is no fieldwork, however, obviously wetlands in and downstream of the study area could indirectly benefit

(4) Are there any known archeological sites in the proposed project area?
Yes, but they would not be affected by any activity associated with the research.

(5) Will the research project result in any modification of, or affects to, individual features of a water delivery system (e.g., headgates, canals)?
No, not directly, however, information gained regarding forecasts of possible shifts of preferred habitat may allow prioritization of water delivery system features to assure unimpeded connectivity to allow for movements.

Required Permits or Approvals
No permits required

Funding Plan and Letters of Commitment

1) The amount of funding commitment
The University of Texas at Austin has waived Indirect Costs (total $86,125) for this proposal, and the PIs each contribute 1 month of salary and fringe in each of the two years of the project, thus providing $42,695 in cost-share.

2) The date the funds will be available to the applicant
on signing of contract

3) Any time constraints on the availability of fund
None

4) Any other contingencies associated with the funding commitment
None

Cost share funding:

1) How you will make your contribution to the cost-share requirement, e.g., monetary and/or in-kind contributions and the sources of funds you will contribute (e.g., reserve account, tax revenue, and/or assessments).
Waived indirect and In-kind contributions

2) Describe any in-kind costs incurred before the anticipated project start date that you seek to include as project costs.

(a) What project expenses have been incurred - None

(b) How they benefitted the project – N/A

(c) The amount of the expense – N/A

(d) The date of cost incurrence – N/A

3) Provide the identity and amount of funding to be provided by funding partners, as well as the required letters of commitment. - None

4) Describe any funding requested or received from other Federal partners. - None

5) Describe any pending funding requests that have not yet been approved, and explain how the project will be affected if such funding is denied. – None
Table 2 summarizes non-Federal and other Federal funding sources. In-kind contributions are marked with an asterisk (*).

Table 2. Summary of non-Federal and Federal funding sources

Funding Sources	Funding Amount
Non –Federal Entities	

1. **University of Texas at Austin**	**$94,653***
Non-Federal Subtotal	**$94,653***
Other Federal Entities	
None	
Other Federal Subtotal	**$0**
Requested Reclamation Funding	**$94,637**
Total Project Funding	**$189,290**

Budget Proposal
Table 3. Budget Proposal

Budget Item Description		Computation			Recipient Funding	Reclamation Funding	Total Cost
		$/Unit	Unit	Quantity			
Salaries And Wages							
Hendrickson (includes 4% raise in yr2)		$7,623	FTE month	2.0	$15,551	$0	$15,551
Sarkar (includes 4% raise in yr2)		$9,822	FTE month	2.0	$20,037	$0	$20,037
Research Asst. 1 (part time) (yr 1 @ starting rate + yr 2 @ 1.04* starting rate)		$4,300	FTE month	6.0	$0	$25,797	$25,797
Research Asst. 2 (part time) (yr 1 @ starting rate + yr 2 @ 1.04* starting rate)		$3,556	FTE month	6.0	$0	$21,905	$21,905
Research Asst. 3 (georeferencing expert) (part time) (yr 1 @ starting rate + yr 2 @ 1.04* starting rate)		$2,906	FTE month	4.0	$0	$11,624	$11,624
Fringe Benefits							
Full-Time Employees (Hendrickson 28%, Sarkar 18%)		$3,902	FTE month		$7,961		$7,961
Part-Time Employees (28% avg.)	28%				$0	$16,611	$16,611
Travel							
average trip for professional meeting presentations (2 people)		$2,000	ea	2.0	$0	$4,000	$4,000
Equipment							
Desktop workstation for GIS and modeling - Dell Precision T5500 64bit Dual Processor, 12 gb memory, 2 gb video, dual hard drives, dual monitors		$7,400	ea	1.0	$0	$7,400	$7,400
laptop computer and external monitor for assistants		$2,000	ea	1.0	$0	$2,000	$2,000
							$0
Supplies/Materials							
computer maintenance, network storage		$800	ea	2.0	$0	$1,600	$1,600
publication costs		$1,350	ea	2.0	$0	$2,700	$2,700
software upgrades / licenses		$500	ea	2.0	$0	$1,000	$1,000
Construction							$0
Contractual							$0
Environmental And Regulatory							$0
Other							$0
Reporting							$0
Total Direct Costs					$43,549	$94,637	$138,186
Indirect Costs	**54.0%**				$51,104	$0	$51,104
Total Project Costs					$94,653	$94,637	$189,290

Budget Narrative

The following supplements Table 3 by providing additional information and justification for key line items in the Budget Proposal.

(a) Salaries and Wages: Program manager: Dr. Dean Hendrickson. Other key personnel: Dr. Sahotra Sarkar. Each contributes one month of their time paid by the university in each project year. Hendrickson's time in the first year will be spent on primary requests and acquisition of data in month one and afterward supervision and coordination of assistants and oversight of all aspects of the project. Sarkar's time will be primarily dedicated to coordination and oversight of modeling in both years. Other personnel include 3 research assistants: one (number 1 in budget) will work on this project for 12 months at 20 hrs/week (=6 FTE) and be primarily responsible for data compilation and quality control. Another assistant (2 in budget) primarily responsible for modeling and climate change impact forecasting will be appointed for a total of 10 part time (20 hrs/wk) months (=5 FTE) starting later in the project when the data are ready for modeling. The third (3 in budget) assistant will work 20 hrs/wk for 8 months (=4 FTEs) starting early in the first project year doing primarily georeferencing of data and other basic normalization tasks. All salaries are of actual current employees with extensive experience in the tasks they would be doing for this project. For all appointments that extend into project year 2, a 4% raise is included.

(b) Fringe Benefits: Rates for PIs are current actual rates for each individual (but still potentially subject to change). Fringe for current assistants averages 28% so that rate is applied across all in the budget and 28% is the recommended average of all UT employees in similar positions.

(c) Travel: Travel is budgeted for participation by two research group members (PIs, Research Assistants) to present research results at 2 unspecified professional meetings (possibilities listed above). It is not possible at this time to say which meetings will be attended and thus provision of detailed cost breakdown for travel is not possible. Experience tells us that $2,000 is usually adequate to cover travel, lodging, and per diem for two people to regional domestic professional meetings.

(d) Equipment: A fast, dual processor desktop workstation is required for the intensive GIS work with the large data sets we propose to work with. Large local disk storage, large amounts of memory and vast video processors are also required for the same reasons. Dual (or more) monitors are nearly indispensable for working with such data. Quote from Dell Premium website.

Assistants will be part time employees on this project with possibly other simultaneous appointments on other projects that may require travel. A laptop is required to allow them to continue work during such travel or to work from home when sometimes required for other reasons. In the office a separate monitor helps make work on laptops much more efficient. Quote from Dell Premium website.

Both computers purchased for this project will be used exclusively for work on this project.

(e) Materials and Supplies: Our lab policy that local computer storage (e.g. that on the computers we propose to purchase) is used only for temporary storage of working copies of data. Our original and master compiled data sets are stored as read-only copies on shared, secure and reliably backed-up university network servers where projects are charged for storage at the rate of $5/gb/yr. Standard UT IT support for the two computers we propose here to purchase is $200 - $400/yr. per computer. We thus budget $800/yr for these services.

Publication costs ($1350/paper) are those of PLoS One, a relatively new, but highly regarded open access journal where we have recently had some of our recent research using the FoTX data accepted for publication. We propose to publish at least 2 papers from this project. Though they may not necessarily be accepted to PLoS One, these costs are reasonable estimates for costs of publishing in other journals.

Our research is highly dependent on keeping specialized licensed software (e.g. GIS) up to date. University-negotiated licenses are reasonable. $500/yr will cover those costs.

(f) Contractual: none

(g) Environmental and Regulatory Compliance Costs: None

(h) Reporting: All costs for reporting and dissemination of results are included in personnel salaries and wages, and in supplies.

(i) Other: No other expenses.

(j) Indirect: University of Texas at Austin's current indirect rate is 54%, but it is here waived and provided to this project as cost share.

(k) Contingency Costs: None.

(l) Total: $189,290; Federal share $94,637; $94,653

Table 1. Data for priority species known from shared US-Mexico river basins of the Desert LCC east of the Colorado River. Data were compiled from GBIF, Fishnet2, SONFISHES and UMMZ. Subspecies marked with (*) were treated as species and taxa occurring only in the US are flagged (US). This preliminary summary of most of the data we propose to process for this project indicates that over 12,000 records for these priority species (as well as many more for species not ranked by Nature Serve – our preliminary database has 32,527 total species occurrence records) will be provided. Additionally, we will also provide 9,917 records already fully processed in our FoTX database (www.fishesoftexas.org) and many newer records from UNM's Museum of Southwestern Biology that were not available for this preliminary summary.

No.	Genus species subspecies	Common name	Drainage	NatureServe Global Status	Nature Serve Lowest State-level Status	N records
1	*Xyrauchen texanus*	Razorback Sucker	Gila	G1	AZ,NM-S1	1
2	*Cyprinodon eremus*	Quitobaquito Pupfish	Sonoyta	G1	AZ-S1	26
3	*Cyprinodon macularius*	Desert Pupfish	Gila and Colorado	G1	AZ-S1	51
4	*Gila purpurea*	Yaqui Chub	Yaqui	G1	AZ-S1	145
5	*Gila nigrescens*	Chihuahua Chub	Casas Grandes	G1	NM-S1	207
6	*Cyprinodon pecosensis* US	Pecos Pupfish	Río Grande	G1	TX,NM-S1	42
7	*Cyprinodon bovinus* US	Leon Springs Pupfish	Río Grande	G1	TX-S1	1
8	*Cyprinodon elegans* US	Comanche Springs Pupfish	Río Grande	G1	TX-S1	7
9	*Dionda diaboli*	Devils River Minnow	Río Grande	G1	TX-S1	19
10	*Gambusia clarkhubbsi* US	San Felipe Gambusia	Río Grande	G1	TX-S1	0
11	*Gambusia gaigei*	Big Bend Gambusia	Río Grande	G1	TX-S1	14
12	*Hybognathus amarus*	Río Grande Silvery Minnow	Río Grande	G1	TX-SX	18
13	*Ictalurus sp.*	Chihuahua Catfish	Río Grande	G1G2	TX-S1S2	206*
14	*Gila ditaenia*	Sonora Chub	Concepción	G2	AZ-S1	107
15	*Ictalurus pricei*	Yaqui Catfish	Yaqui	G2	AZ-S1	122
16	*Meda fulgida*	Spikedace	Gila	G2	AZ-S1	41
17	*Rhinichthys cobitis*	Loach Minnow	Gila	G2	AZ-S1	34
18	*Gambusia nobilis* US	Pecos Gambusia	Río Grande	G2	NM-S1	15
19	*Gila intermedia*	Gila Chub	Gila	G2	NM-S1	4
20	*Dionda argentosa*	Manantial roundnose Minnow	Río Grande	G2	TX-S2	0
21	*Etheostoma grahami*	Río Grande Darter	Río Grande	G2G3	TX-S2	54
22	*Gila nigra*	Headwater Chub	Gila	G2Q	AZ-S2	0
23	*Notropis simus pecosensis* US	Pecos bluntnose Shiner	Río Grande	G2T2	NM-S2	17*
24	*Notropis simus simus*	Bluntnose Shiner	Río Grande	G2TX	NM-SX	17*
25	*Gila robusta*	Roundtail Chub	Gila	G3	AZ,CO,NM-S2	170
26	*Cyprinella formosa*	Beautiful Shiner	Casas Grandes	G3	AZ-S1	212
27	*Ictalurus lupus*	Headwater Catfish	Río Grande	G3	NM-S1	309
28	*Notropis jemezanus*	Río Grande Shiner	Río Grande	G3	NM-S2	290
29	*Poeciliopsis occidentalis occidentalis*	Gila Topminnow	Gila	G3	NM-SX	130*
30	*Gila pandora*	Río Grande Chub	Río Grande	G3	TX-S1	98
31	*Moxostoma austrinum*	Mexican Redhorse	Río Grande	G3	TX-S1	84
32	*Cyprinella proserpina*	Proserpine Shiner	Río Grande	G3	TX-S2	35
33	*Notropis chihuahua*	Chihuahua Shiner	Río Grande	G3	TX-S2	210
34	*Catostomus plebeius*	Río Grande Sucker	Río Grande	G3G4	CO-S1	171
35	*Cycleptus elongatus*	Blue Sucker	Río Grande	G3G4	NM-S1	12
36	*Catostomus clarki*	Desert Sucker	Gila	G3G4	NM-S2	36
37	*Catostomus insignis*	Sonora Sucker	Gila	G3G4	NM-S2	86
38	*Etheostoma lepidum* US	Green Throat Darter	Río Grande	G3G4	NM-S2	8
39	*Macrhybopsis aestivalis*	Speckled Chub	Río Grande	G3G4	NM-S2	341
40	*Campostoma ornatum*	Mexican Stoneroller	Río Grande &Yaqui	G3G4	TX-S1	730
41	*Cyprinodon eximius*	Conchos Pupfish	Río Grande	G3G4	TX-S1	92
42	*Atractosteus spatula*	Alligator Gar	Río Grande	G3G4	TX-S4	0
43	*Gambusia senilis*	Blotched Gambusia	Río Grande	G3G4	TX-SX	159
44	*Gambusia speciosa*	Tex-Mex Gambusia	Río Grande	G3Q	TX-S3	45
45	*Cyprinella formosa mearnsi*	Yaqui Shiner	Yaqui	G3T2	n/a	212*
46	*Poeciliopsis occidentalis sonoriensis*	Yaqui Topminnow	Yaqui	G3T3	AZ-S1	130*
47	*Catostomus bernardini*	Yaqui Sucker	Yaqui	G4	AZ-SX	261
48	*Hybognathus placitus*	Plains Minnow	Río Grande	G4	CO-SH	57
49	*Moxostoma congestum*	Gray Red Horse	Río Grande	G4	NM-S1	265
50	*Anguilla rostrata*	American Eel	Río Grande	G4	NM-SX	35
51	*Notropis amabilis*	Texas Shiner	Río Grande	G4	NM-SX	275
52	*Scaphirhynchus platorynchus*	Shovelnose Sturgeon	Río Grande	G4	NM-SX	1
53	*Notropis braytoni*	Tamaulipas Shiner	Río Grande	G4	TX-S4	414
54	*Agosia chrysogaster ssp.*	Yaqui Longfin Dace	Yaqui	G4T1	NM-SNA	211*
55	*Oncorhynchus clarki virginialis* US	Río Grande Cutthroat	Río Grande	G4T3	NM-S2	28

No.	Genus species subspecies	Common name	Drainage	NatureServe Global Status	Nature Serve Lowest State-level Status	N records
56	*Agosia chrysogaster chrysogaster*	Gila Longfin Dace	Gila	G4T3T4	NM-SNA	211*

Table 1. *Continued*

No.	Genus species subspecies	Common name	Drainage	NatureServe Global Status	Nature Serve Lowest State-level Status	N records
57	*Phenacobius mirabilis* [US]	Suckermouth Minnow	Río Grande	G5	NM,CO-S2	14
58	*Semotilus atromaculatus* [US]	Creek Chub	Río Grande	G5	NM,TX-S3	69
59	*Astyanax mexicanus*	Mexican Tetra	Río Grande	G5	NM-S2	3814
60	*Lepisosteus osseus*	Longnose Gar	Río Grande	G5	NM-S2	34
61	*Percina macrolepida*	Bigscale Logperch	Río Grande	G5	NM-S2	6
62	*Ictalurus furcatus*	Blue Catfish	Río Grande	G5	NM-S2S3	58
63	*Dionda episcopa*	Roundnose Minnow	Río Grande	G5	NM-S3	363
64	*Ictiobus bubalus*	Smallmouth Buffalo	Río Grande	G5	NM-S3	28
65	*Lucania parva*	Rainwater Killifish	Río Grande	G5	NM-S3	108
66	*Rhinichthys osculus*	Speckled Dace	Gila	G5	NM-S3	110
67	*Platygobio gracilis* [US]	Flathead Chub	Río Grande	G5	NM-S4	91
68	*Awaous banana*	River Goby	Río Grande	G5	TX-S1	43
69	*Rhinichthys cataractae*	Longnose Dace	Río Grande	G5	TX-S2	246
70	*Cyprinella lutrensis blairi* [US]	Maravillas red Shiner	Río Grande	G5TX	TX-X	889*
71	*Ctenogobius claytonii*	Mexican Goby	Río Grande	GNR	TX-S1	0
72	*Notropis orca*	phantom Shiner	Río Grande	GXQ	TX-SX	4
73	*Cyprinus carpio*	Common Carp	Río Grande	Non-native	Non-native	295
74	*Hypostomus sp.*	Armored Catfish	Río Grande	Non-native	Non-native	0
75	*Lepomis auritus*	Redbreast Sunfish	Río Grande	Non-native	Non-native	0
76	*Micropterus dolomieu*	Smallmouth Bass	Río Grande	Non-native	Non-native	7
77	*Morone chrysops*	White Bass	Río Grande	Non-native	Non-native	17
78	*Morone saxatilis*	Striped Bass	Río Grande	Non-native	Non-native	0
79	*Oreochromis aureus*	Blue Tilapia	Río Grande	Non-native	Non-native	116